Principal Prey Species and Periodicity of their Incidence in Stomachs of Trawl-Caught Pacific Cod *(Gadus macrocephalus)*, Rock Sole *(Lepidopsetta bilineata)*, and Petrale Sole *(Esopsetta jordani)* Landed in British Columbia, 1950-80

S. J. Westrheim and W. R. Harling

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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PRINCIPAL PREY SPECIES AND PERIODICITY OF THEIR INCIDENCE IN STOMACHS OF TRAWL-CAUGHT PACIFIC COD (*Gadus macrocephalus*), ROCK SOLE (*Lepidopsetta bilineata*), AND PETRALE SOLE (*Eopsetta jordani*) LANDED IN BRITISH COLUMBIA, 1950-80

by

S. J. Westrheim and W. R. Harling

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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ABSTRACT

Westrheim, S. J., and W. R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (Gadus macrocephalus), rock sole (Lepidopsetta bilineata), and petrale sole (Eopsetta jordani) landed in British Columbia, 1950-80. Can. MS Rep. Fish. Aquat. Sci. 1681: iv + 38 p.

Prey incidence was compiled from port liaison officers' notes recorded while collecting length-frequency samples of Pacific cod (Gadus macrocephalus), rock sole (Lepidopsetta bilineata), and petrale sole (Eopsetta jordani) in trawl landings originating from three major offshore regions of British Columbia during 1950-80. Principal prey species were sandlance (Ammodytes hexapterus), herring (Clupea harengus pallasi), "shrimp" (assorted Crustacea) and sablefish (Anoplopoma fimbria), the latter only in Pacific cod stomachs. Sandlance was an important prey species for all three predator species and in all three offshore regions. Incidence periodicity was demonstrated for sandlance ($\bar{X}$ = 4.2y); herring off the west coast of Vancouver Island ($\bar{X}$ = 3.9y); and sablefish in Hecate Strait (7-9 y).

Key words: diet, Pacific cod, petrale sole, rock sole.

RÉSUMÉ

Westrheim, S. J., and W. R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (Gadus macrocephalus), rock sole (Lepidopsetta bilineata), and petrale sole (Eopsetta jordani) landed in British Columbia, 1950-80. Can. MS Rep. Fish. Aquat. Sci. 1681: iv + 38 p.

Le présent rapport contient une compilation des fréquences des proies notées de 1950 à 1980 par les agents de liaison du port au cours de la collecte d'échantillons de fréquence des longueurs des morues du Pacifique (Gadus macrocephalus), des soles du Pacifique (Lepidopsetta bilineata) et des plies de Californie (Eopsetta jordani) dans les débarquements de chalutiers provenant de trois grandes régions de pêche hauturière en Colombie-Britannique. Les principales espèces-proies sont les suivantes: le lançon gourdeau (Ammodytes hexapterus), le hareng du Pacifique (Clupea harengus pallasi), les crevettes (divers crustacés) et la morue charbonnière (Anoplopoma fimbria), cette dernière n'étant retrouvée que dans les estomacs de morue du Pacifique. Le lançon gourdeau est une importante espèce-proie

pour les trois espèces prédatrices dans les trois régions hauturière. La périodicité de la fréquence est prouvée pour le lançon gourdeau (X = 4,2 années), le hareng au large de la côte ouest de l'île Vancouver ($\bar{X}$ = 3,9 années) et la morue charbonnière dans le détroit d'Hécate ($\bar{X}$ = 7 à 9 années).

Mots-clés: régime, morue du Pacifique, plie de Californie, sole du Pacifique

INTRODUCTION

Pacific cod (Gadus macrocephalus) is an important component in the trawl fishery off British Columbia. Its substantial, but unpredictable, fluctuations in abundance are of considerable concern to industry, managers, and scientists alike. Recently, studies have been undertaken to determine the causes of these fluctuations, and develop a method for predicting abundance. Conventional approaches using environmental parameters such as sea level and temperature are underway.

Another line of inquiry, not heretofore attempted for cod, was inspired by Keith and Windberg (1978), who demonstrated that the Arctic hare, a popular prey species, generates its own substantial fluctuations in abundance--predator abundance merely reflects these cycles. By analogy, perhaps the abundance cycles of codfish prey might be a factor in abundance cycles of codfish. Sandlance (Ammodytes hexapterus) is an important component in the diet of codfish and numerous other species of marine fishes and mammals. Anecdotal evidence suggests that sandlance exhibit similar abundance cycles to cod. Indeed their life histories are strikingly similar--short life, rapid growth; demersal, adhesive eggs fertilized externally (Trumble 1973).

The first step in this study was to locate and investigate any long-term data series which involved sandlance. Such a series was found in the length-frequency sample records of groundfish trawl landings in British Columbia. As these samples were taken, the sampler would frequently record the stomach contents as a general note for each sample.

Results of this inquiry deal with length-frequency records for Pacific cod, rock sole (Lepidopsetta bilineata), and petrale sole (Eopsetta jordani). A fourth important trawl-caught piscivore is lingcod (Ophiodon elongatus), but this species is normally eviscerated at sea, and hence its sample records were not suitable. In the course of data compilation, other prey species appeared to be worthy of consideration and were also included.

This report summarizes the information collected during 1950-80 with respect to incidence, and periodicity of "abundance", of principal prey species reported in the length-frequency samples collected from B.C. trawl landings of Pacific cod, rock sole, and petrale sole from offshore grounds. Sampling records from the highly seasonal fishery in Georgia Strait (Area 4B) are not included in this study.

MATERIALS AND METHODS

All length-frequency sample records of Pacific cod, rock sole, and petrale sole caught on offshore grounds were examined for samplers' notations

of stomach contents. All samples containing notes on stomach contents were termed "evaluated samples". Incidence of prey species was expressed as a percentage of evaluated samples in which the particular prey species occurred.

Samplers' notes on stomach contents were not, nor were they intended to be, quantitative. The three principal samplers (see ACKNOWLEDGMENTS) were interviewed in October 1982 by the senior author with respect to how each evaluated stomach contents. All reported that incidence of prinicpal prey species was based on several occurrences in any sample. None reported a bias against reporting "empty" stomachs.

Records of prey species incidence for each predator species were initially compiled by fishing ground, but subsequently were combined by major regions--Hecate Strait (Area 5C and 5D), Queen Charlotte Sound (Areas 5A and 5B), and off the west coast of Vancouver Island (Areas 3C and 3D) (Fig. 1). Exceptions to this procedure were made for herring and sablefish in Hecate Strait.

Periodicity of "abundance" for principal prey species was investigated by noting the time interval between modal incidence percentages, where suitable time series were available. When sandlance were noted, the sampler occasionally recorded the size, as "very small", "small", "medium", or "large". "Small" was sometimes noted further as "approximately 8 cm" and "medium" as "approximately 15 cm". These data were collated for comparison with the aforementioned periodicity studies.

RESULTS

GENERAL

During 1950-80, 2,920 length-frequency samples of the three prey species were collected from trawl landings in British Columbia, originating on the offshore banks--1,192 of Pacific cod; 1,033 of rock sole; and 695 of petrale sole (Table 1). Of these, 1,751 were "evaluated samples" -- 453 of Pacific cod; 735 of rock sole; and 563 of petrale sole. The relatively low proportion of evaluated samples among Pacific cod samples was due to at least two factors. First, cod were often eviscerated at sea, particularly in the earlier years. Neither rock sole nor petrale sole were eviscerated at sea. Second, processors were sometimes reluctant to permit the sampler to cut open the visceral cavity. Flatfish were more readily sampled after filleting, and hence stomach contents were readily determined. The relatively high proportion of evaluated samples among total samples of petrale sole reflects the considerable attention paid to this species, particularly prior to 1970. Petrale sole is in constant demand and commands a high price.

Within regions, numbers of evaluated samples for each species did not reflect relative magnitude of landings. Rock sole samples comprised 52% of the total samples from Hecate Strait and 58% from Queen Charlotte Sound (Table 1), but Pacific cod landings were larger (Fig. 2-3). Petrale sole samples comprised 71% of the total evaluated samples from off Vancouver Island, but again Pacific cod landings were substantially larger (Fig. 4).

Principal prey species reported were sandlance, herring (Clupea harengus pallasi), and "shrimp"[1] (Table 2). A secondary species, found only in cod stomachs, was sablefish (Anoplopoma fimbria), which are too large to be ingested by rock sole or petrale sole. Incidence of empty stomachs was small for Pacific cod (0-3%) and petrale sole (3-5%), but relatively large for rock sole (7-28%), particularly in Hecate Strait (28%). Rock sole is suspected of heavy nocturnal feeding in some areas while trawling occurs mostly during daylight hours. Detailed records by region and year are shown in Appendix Tables 1-3 for Pacific cod, 4-6 for rock sole, and 7-9 for petrale sole.

PACIFIC COD

Among regions, principal prey species in Pacific cod samples were sandlance (52-83% of evaluated samples) and herring (39-43%) (Table 2). Secondary species were "shrimp" (11-19%) and sablefish, the latter primarily in Hecate Strait (16%). Seasonally, sandlance incidence was maximal during Quarters II and III in Hecate Strait (84 and 64%) and Queen Charlotte Sound (83 and 93%), and during Quarters I and II off Vancouver Island (72 and 64%) (Table 3). Seasonal incidence of herring in cod samples was maximal during Quarters I and IV in Hecate Strait (66 and 78%) and Queen Charlotte Sound (100%); but Quarters III and IV off Vancouver Island (75 and 100%). "Shrimp" exhibited little seasonal incidence except in Hecate Strait--maximal incidence occurred during Quarters II and III (11 and 21%). Sablefish incidence in cod samples from Hecate Strait was maximal in Quarters I and IV (25 and 30%).

Within Hecate Strait, seasonal incidence of sandlance and herring reflected the corresponding bathymetric migrations of cod. During spring and summer, cod are most often found in shallower water, where sandlance predominate. During fall and winter, cod are most often found in deeper water where they spawn during January-March, and where herring congregate prior to spawning, at the same time, in nearby inlets. Thus on White Rocks Ground, the principal spawning area for cod in Hecate Strait, herring incidence is high in the fall (90%) and winter (84%) samples (Fig. 5; Table 4). For the rest of Hecate Strait, sandlance incidence is high principally during spring and summer (57-100%).

"Shrimp" and sablefish incidence reflected localized distributions. "Shrimp" incidence was relatively high (21-29%) only in Area 5D exclusive of White Rocks Ground, during Quarters II-IV (Table 4). Sablefish incidence was high (32-35%) during Quarters I, II, and IV on White Rocks Ground; and high during Quarters III and IV (20-22%) elsewhere in Area 5D and Quarter I (18%) in Area 5C.

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[1] Assorted Crustacea, including copepods, euphausiids, munids, and pandalids.

ROCK SOLE

In rock sole samples, principal prey was sandlance in all area-time cells--33-100% (Tables 2 and 3). "Shrimp" was moderately important off Vancouver Island during Quarters II-IV (24-50%). Herring incidence was negligible in Hecate Strait (0-2%), and zero elsewhere.

PETRALE SOLE

In petrale sole samples, principal prey species were sandlance, herring, and "shrimp" (Table 2). Sandlance were important during Quarters II and III in all regions (30-87%), but to a greater extent in Hecate Strait (73 and 56%) and Queen Charlotte Sound (87 and 79%) (Table 3).

Herring incidence in petrale sole samples was relatively high in Hecate Strait (32%) and off Vancouver Island (37%), but not in Queen Charlotte Sound (8%) (Table 2). Seasonally, herring incidence was relatively high (40-71%) in all regions during autumn (Qtr IV); and relatively high (29-71%) during all seasons off Vancouver Island (Table 3). Records from off Vancouver Island often contained the observation that "large" petrale sole contained herring and "small" petrale (in the same sample) contained "shrimp".

"Shrimp" incidence was relatively high (21-78%) in all area-time cells where at least 18 samples were collected. There was no evident seasonal pattern.

PERIODICITY OF PREY SPECIES

Sandlance

Periodicity of sandlance "abundance" was determined with the following time series during which annual numbers of evaluated samples were reasonably substantial:

Predator species	Hecate Strait[a]	Queen Charlotte Sound	West coast Vancouver Island
Pacific cod	1954-66 1976-79	1977-80	1977-80
Rock sole	1950-71 1977-80	1950-69 1978-80	1950-54
Petrale sole	1957-67	1957-67	1950-71

[a]Excluding White Rocks Ground.

Using modal incidence values in Table 5, the following time periods emerge as "high-abundance" periods for sandlance: 1951-52, 1955-58, 1960-62, 1964-65, 1967-68, 1971, 1973-75, and 1978-79. Time interval between modes ranged from 2 to 5 y, with a mean of 3.9 y.

Size classes of sandlance were reported occasionally (Appendix Table 10). From these limited data, rough time progressions from "small" to "large" were evident for 1965-69 in Hecate Strait, 1959-69 in Queen Charlotte Sound, and 1965-69 off west Vancouver Island (Table 6). Time of progression from "small" to "large" appears to be about 2 y. In June 1966, a midwater trawl survey in Queen Charlotte Sound encountered sandlance, and the combined length-frequencies from the catches are shown in Fig. 5. Presumably, these would have been classed as "very small", "small", and "medium" by the port samplers if encountered in stomachs of predator species, and probably represent age classes 0, 1, and 2.

Herring

Periodicity of herring "abundance" is not evident in the Pacific cod and petrale sole samples from Hecate Strait or Queen Charlotte Sound (Table 7). The absence of Pacific cod samples from White Rocks Ground during 1967-72 coincides with the depletion of herring (Hourston 1980), closure of the reduction fishery, and a sharp decline in cod landings (but not cod abundance) from White Rocks Ground during the winter (Stocker 1981). Off Vancouver Island, peak incidence percentages in petrale sole samples occurred in 1953, 1958, 1961, 1965, 1969, 1974, and 1978. Time intervals between modal incidences ranged from 3 to 5 y, with a mean of 4.2 y. Pacific cod samples were not sufficient to provide any insight into herring periodicity.

SABLEFISH

Only Pacific cod samples contained records of sablefish--16% from Hecate Strait; 5% from Queen Charlotte Sound; and 1% from the west coast of Vancouver Island (Table 2). Occasionally, the size of sablefish was noted, as 20-25 cm or 40-45 cm, and these size classes probably represent ages 1+ and 2+, respectively.

In Hecate Strait, 47 of the 48 samples were from Two-Peaks Butterworth (17) and White Rocks-Bonilla (30) grounds in Area 5D, and the remaining sample was from Reef Island Ground (Fig. 5). Periodicity of incidences was evident for both Two Peaks-Butterworth and White Rocks-Bonilla grounds (Table 8). One peak occurred in 1959 on White Rocks-Bonilla Ground (67%) and in 1960 on Two Peaks-Butterworth Ground (67%). The second appeared in 1979 (25 and 50%) on both grounds. Unfortunately, samples were scarce during 1967-75 on both grounds, and a third peak in incidence may have been missed. G. A. McFarlane (pers. comm.) reported that the 1967 or 1968 year class was especially abundant.

In Queen Charlotte Sound, only three Pacific cod samples contained sablefish, and these occurred in 1977 (1/12) and 1978 (2/23). Few samples were collected prior to 1976 (Table 8).

Off Vancouver Island, one sample contained sablefish, and it was collected in 1979 (1/17). Few samples were collected prior to 1973 (Table 8).

CONCLUSIONS

Records of length-frequency samples collected from B.C. trawl landings of Pacific cod, rock sole, and petrale sole from offshore grounds during 1950-80 have yielded considerable useful information with respect to the diet of these three species and the identity and periodicity of their principal prey species.

Principal prey species were sandlance, herring, "shrimp", and sablefish (only for Pacific cod). Sandlance was an important prey for all three predator species in all three offshore regions. Herring was an important prey for Pacific cod and petrale sole in all three regions. "Shrimp" was important to Pacific cod and petrale sole in Hecate Strait and Queen Charlotte Sound; and to all three species off Vancouver Island. Sablefish was a prey only for Pacific cod, and only important in Hecate Strait. Seasonally, sandlance was the most important prey during spring-summer, while herring and sablefish were most important during autumn-winter. "Shrimp" was generally most important during winter-spring.

Incidence ("abundance") periodicity was demonstrated for three important prey species based on stomach contents of Pacific cod, rock sole, and/or petrale sole. "Abundance" periodicity was 2-5 y ($\overline{X}$ = 3.9 y) for sandlance; 3-5 y ($\overline{X}$ = 4.2 y) for herring (off Vancouver Island); and approximately 7-9 y for sablefish (in Hecate Strait).

Unfortunately, incidence periodicity only demonstrates qualitative fluctuations in abundance.

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Table 1. Inventory of evaluated (E) and total (T) samples collected from British Columbia trawl landings, by species and region, 1950-80.

Region	Sample type[a]	Species						Total	
		Pacific cod		Rock sole		Petrale sole			
		N	%	N	%	N	%	N	%
Hecate Strait (Areas 5C & 5D)	E	304	38	410	52	82	10	796	100
	(T)	(658)		(589)		(98)		(1,345)	
Queen Charlotte Sound (Areas 5A & 5B)	E	66	14	264	58	129	28	459	100
	(T)	(164)		(367)		(149)		(680)	
Vancouver Island (Areas 3C & 3D)	E	83	17	61	12	352	71	496	100
	(T)	(370)		(77)		(448)		(895)	
Total		453	26	735	42	563	32	1,751	100
		(1,192)[a]		(1,033)		(695)		(2,920)	

[a]Excluding 972 samples from landings of cod eviscerated at sea.

Table 2. Incidence (%) of principal prey species in evaluated samples of Pacific cod, rock sole, and petrale sole, by region, 1950-80.

Region	Predator species[a]	Evaluated samples	% Samples containing: Sand-lance	Herring	"Shrimp"[b]	Sable-fish	Other[c]	Nil
Hecate Strait	PC	304	52	39	11	16	13	3
(Areas 5C & 5D)	RS	410	63	1	7	0	6	28
	PS	82	42	32	29	0	17	5
Queen Charlotte Sound	PC	66	83	39	15	5	5	0
(Areas 5A & 5B)	RS	264	81	0	6	0	5	13
	PS	129	81	8	30	0	3	3
Vancouver Island	PC	83	59	43	19	1	21	2
(Areas 3C & 3D)	RS	61	75	0	28	0	15	7
	PS	352	36	37	71	0	8	3

[a] PC = Pacific cod; PS = petrale sole; RS = rock sole.

[b] Includes euphausiids and pandalids, etc.

[c] See Appendix Table 1-9.

Table 3. Incidence (%) of principal prey species in evaluated samples of Pacific cod, rock sole, and petrale sole, by region and quarter year, 1950-80.

Region	Qtr	Evaluated samples	% Samples containing: Sand-lance	Herring	"Shrimp"	Sable-fish	Other	Nil
				Pacific cod				
Hecate Strait	I	85	15	66	5	25	17	5
(5C & 5D)	II	109	84	14	11	4	10	1
	III	70	64	21	21	16	6	3
	IV	40	15	78	5	30	10	3
Queen Charlotte Sound	I	2	0	100	0	0	0	0
(5A & 5B)	II	36	83	39	19	3	8	0
	III	27	93	33	7	4	0	0
	IV	1	0	100	100	100	0	0
Vancouver Island	I	25	72	28	16	0	24	4
(3C & 3D)	II	39	64	36	21	3	23	3
	III	16	38	75	19	0	13	0
	IV	3	0	100	33	0	0	0
				Rock sole				
Hecate Strait	I	15	100	0	7	0	0	0
(5C & 5D)	II	162	82	3	9	0	9	10
	III	187	48	0	8	0	4	41
	IV	46	50	2	2	0	7	44
Queen Charlotte Sound	I	10	70	0	10	0	20	10
(5A & 5B)	II	136	88	0	6	0	3	10
	III	115	76	0	7	0	7	17
	IV	3	67	0	0	0	0	33
Vancouver Island	I	7	86	0	0	0	14	0
(3C & 3D)	II	37	76	0	24	0	14	5
	III	14	79	0	50	0	14	7
	IV	3	33	0	33	0	33	0
				Petrale sole				
Hecate Strait	I	0	-	-	-	-	-	-
(5C & 5D)	II	26	73	8	31	0	4	0
	III	18	56	6	39	0	22	0
	IV	38	13	61	24	0	24	11
Queen Charlotte Sound	I	2	0	100	0	0	50	0
(5A & 5B)	II	69	87	7	33	0	0	1
	III	53	79	6	21	0	4	6
	IV	5	60	40	60	0	0	0
Vancouver Island	I	2	0	50	0	0	0	50
(3C & 3D)	II	152	30	29	78	0	9	3
	III	177	45	38	67	0	8	3
	IV	21	19	71	67	0	0	5

Table 4. Incidence (%) of principal prey species in evaluated samples of Pacific cod from selected areas of Hecate Strait, by quarter year, 1950-80.

Area	Qtr	Evaluated samples	% Samples containing: Sand-lance	Herring	"Shrimp"	Sable-fish	Other	Nil
5D -- White Rocks	I	56	4	84	4	32	9	2
	II	4	50	25	25	0	50	0
	III	3	0	67	0	33	0	0
	IV	29	3	90	0	35	7	0
5D -- Other than White Rocks	I	18	39	39	11	6	39	11
	II	48	73	21	20	8	10	2
	III	51	57	26	29	20	8	4
	IV	9	56	33	22	22	22	11
5C -- All	I	11	36	18	0	18	27	9
	II	57	95	7	2	0	7	0
	III	16	100	0	0	0	0	0
	IV	2	0	100	0	0	0	0

Table 5. Incidence (%) of sandlance in evaluated samples of Pacific cod (PC) rock sole (RS), and petrale sole (PS), by area or region, by year, 1950-80.

Year	Hecate Strait (5C & 5D)			Queen Charlotte Sound (5A & 5B)			West Vancouver Island (3C & 3D)		
	PC[a,b]	RS[b]	PS[b]	PC	RS	PS	PC	RS	PS
1950	60 (5)[c]	73	0[d]	100	60	43	-[d]	71	16
1951	33 (3)	74	56	100	100	0	50	63	10
1952	100 (1)	24	-	-	83	67	100	75	38
1953	- (0)	35	33	100	50	25	50	100	33
1954	60 (5)	81	-	-	83	33	50	20	13
1955	67 (6)	100	-	-	100	0	-	100	8
1956	0 (2)	17	100	-	100	100	-	-	38
1957	100 (5)	88	42	100	82	100	-	0	50
1958	88 (8)	48	42	-	93	70	-	75	24
1959	46 (13)	50	100	100	71	80	-	-	60
1960	78 (9)	40	60	-	82	100	100	0	36
1961	100 (5)	17	0	-	95	100	-	-	40
1962	50 (7)	20	14	-	76	86	-	100	67
1963	67 (3)	30	0	-	56	88	-	-	50
1964	69 (13)	80	25	-	71	100	67	100	71
1965	92 (12)	91	80	100	100	100	100	100	69
1966	94 (17)	89	100	100	93	89	60	83	73
1967	100 (2)	55	60	-	100	71	-	100	82
1968	100 (2)	77	0	100	92	100	0	-	33
1969	100 (1)	64	-	-	75	-	-	-	29
1970	- (0)	40	0	-	-	-	-	-	0
1971	- (0)	83	0	-	100	-	-	-	50
1972	- (0)	-	-	-	-	-	-	0	33
1973	33 (3)	100	-	-	-	-	100	100	0
1974	67 (3)	-	-	100	-	0	75	-	67
1975	100 (1)	100	-	-	-	-	0	-	0
1976	67 (6)	100	-	100	50	-	33	-	100
1977	40 (10)	67	-	58	100	-	17	-	33
1978	92 (12)	75	-	100	71	-	61	-	0
1979	70 (33)	57	-	86	100	-	65	-	100
1980	67 (24)	71	-	45	40	-	50	-	0

[a] Excluding White Rocks Ground.

[b] PC = Pacific cod; PS = petrale sole; RS = rock sole.

[c] Number of evaluated samples excluding White Rocks Ground.

[d] 0 = absent in samples; - = no sample.

Table 6. Numbers of evaluated samples of Pacific cod, rock sole, and petrale sole containing sandlance, by sandlance size class[a], by region, for selected years, 1959-69.

Year	Hecate Strait (5C & 5D)			Year	Queen Charlotte Sound (5A & 5B)			Year	Vancouver Island (3C & 3D)		
	S	M	L[a]		S	M	L		S	M	L
1963	2	1	-	1959	1	-	2	1965	2	-	-
1964	-	-	-	1960	4	-	-	1966	2	2	2
1965	9	3	-	1961	3	-	1	1967	-	2	1
1966	18	1	2	1962	-	7	2	1968	-	-	1
1967	4	1	1	1963	3	2	-				
1968	6	-	1	1964	9	1	1				
1969	1	-	1	1965	5	1	-				
				1966	5	-	2				
				1967	3	6	1				
				1968	2	4	-				
				1969	1	-	3				

[a]L=large; M=medium; S=small.

Table 7. Incidence (%) of herring in evaluated samples of Pacific cod (PC) and petrale sole (PS) by region and year, 1950-80. (Numbers of samples in parentheses.)

Year	Hecate Strait (5D)		Queen Charlotte Sound (5A & 5B)		Vancouver Island (3C & 3D)	
	PC[ab]	PS[bc]	PC	PS	PC	PS
1950	-[d] (0)	100 (3)	0[d]	14	-	39
1951	- (0)	40 (5)	0	0	0	40
1952	- (0)	- (0)	-	33	0	52
1953	- (0)	67 (3)	0	50	50	53
1954	100 (5)	- (0)	-	67	50	50
1955	33 (3)	- (0)	-	100	-	46
1956	100 (1)	- (0)	-	0	-	50
1957	100 (1)	88 (8)	0	0	-	0
1958	100 (10)	46 (11)	-	20	-	59
1959	67 (15)	- (0)	100	0	-	30
1960	86 (7)	67 (3)	-	0	0	7
1961	75 (4)	50 (4)	-	0	-	30
1962	100 (5)	14 (7)	-	0	-	13
1963	100 (3)	0 (2)	-	0	-	0
1964	100 (3)	33 (3)	-	0	0	14
1965	100 (5)	0 (2)	0	0	0	23
1966	- (0)	0 (1)	0	0	0	9
1967	- (0)	0 (2)	-	14	-	0
1968	- (0)	- (0)	0	0	0	67
1969	- (0)	- (0)	-	-	-	71
1970	- (0)	- (0)	-	-	-	33
1971	- (0)	100 (1)	-	-	-	38
1972	- (0)	- (0)	-	-	-	0
1973	75 (4)	- (0)	-	0	0	0
1974	- (0)	- (0)	0	0	50	44
1975	100 (2)	- (0)	0	-	100	0
1976	- (0)	- (0)	0	-	100	0
1977	100 (3)	- (0)	58	-	83	67
1978	67 (6)	- (0)	44	-	33	100
1979	50 (4)	- (0)	29	-	71	0
1980	83 (12)	- (0)	67	-	50	0

[a]White Rocks Ground only.

[b]PC=Pacific cod; PS=petrale sole.

[c]Area 5D only.

[d]0 = absent in samples; - = no sample.

Table 8. Incidence (%) of sablefish in evaluated samples of Pacific cod from selected locations in Hecate Strait and Queen Charlotte Sound, by year, 1950-80. (Numbers of samples in parentheses.)

Year	Hecate Strait[a] TP-BU (5D)	Hecate Strait[a] WR (5D)	ReI[b] (5C)	Queen Charlotte Sound (5A + 5B)
1950	0[c] (5)	-[c] (0)	-	0 (2)
1951	0 (2)	- (0)	-	0 (1)
1952	0 (1)	- (0)	-	- (0)
1953	- (0)	- (0)	-	0 (1)
1954	0 (5)	20 (5)	-	- (0)
1955	20 (5)	0 (3)	-	- (0)
1956	0 (2)	0 (1)	-	0 (0)
1957	0 (5)	0 (1)	-	0 (1)
1958	29 (7)	20 (10)	-	- (0)
1959	40 (10)	67 (15)	-	0 (1)
1960	67 (6)	57 (7)	-	- (0)
1961	20 (5)	50 (4)	-	- (0)
1962	33 (3)	0 (5)	-	- (0)
1963	0 (2)	33 (3)	-	- (0)
1964	0 (7)	0 (3)	-	- (0)
1965	0 (6)	0 (5)	-	0 (2)
1966	0 (7)	- (0)	-	0 (1)
1967	0 (2)	- (0)	-	- (0)
1968	0 (2)	- (0)	-	0 (1)
1969	- (0)	- (0)	-	- (0)
1970	- (0)	- (0)	-	- (0)
1971	- (0)	- (0)	-	- (0)
1972	- (0)	- (0)	-	- (0)
1973	- (0)	0 (4)	0 (2)	- (0)
1974	0 (1)	0 (0)	- (0)	0 (2)
1975	- (0)	50 (2)	- (0)	- (0)
1976	0 (3)	0 (0)	- (0)	0 (3)
1977	0 (1)	33 (3)	0 (2)	8 (12)
1978	0 (2)	33 (6)	0 (4)	9 (23)
1979	25 (16)	50 (4)	33 (3)	0 (7)
1980	0 (9)	25 (12)	0 (4)	0 (9)

[a]ReI - Reef Island; TP-BU = Two Peaks-Butterworth; WR = White Rocks Ground.

[b]No fishery until 1967.

[c]0 = absent in samples; - = no samples.

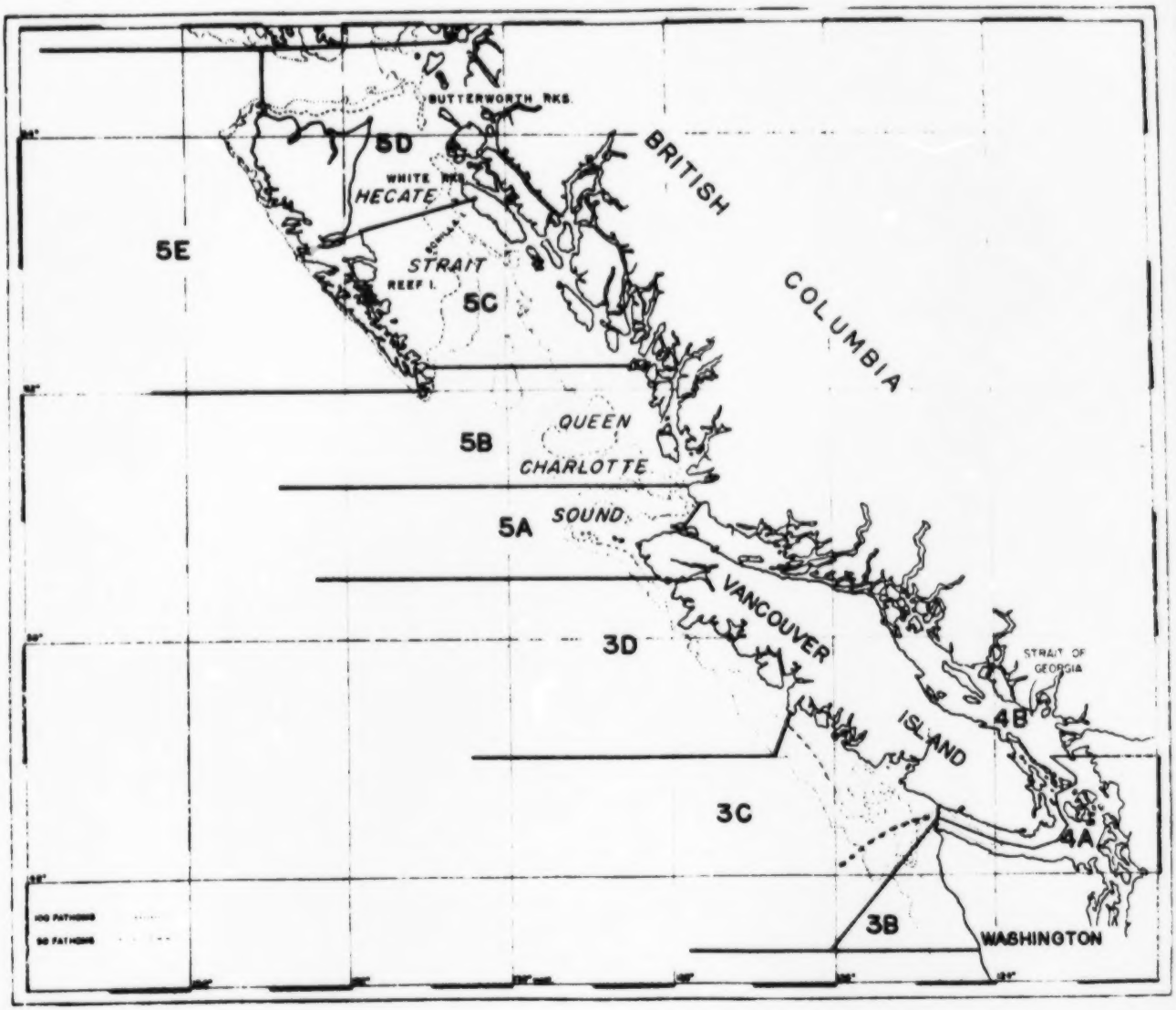

Fig. 1. Canada-U.S. statistical areas for groundfish landings.

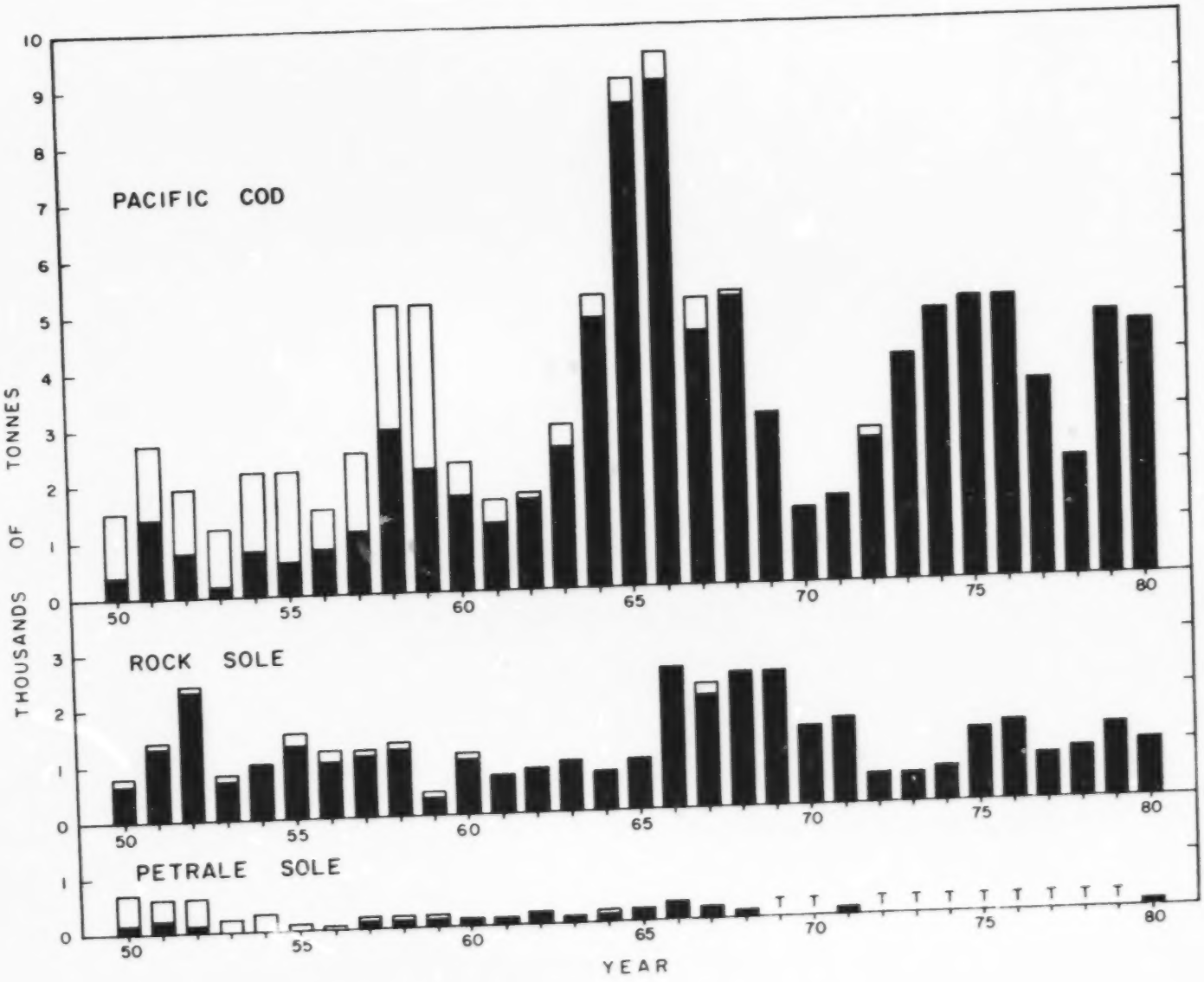

Fig. 2. Canada-U.S. landings (t) of Pacific cod, rock sole, and petrale sole from Hecate Strait (Areas 5C and 5D), 1950-80. (Shaded area = Canadian landings.)

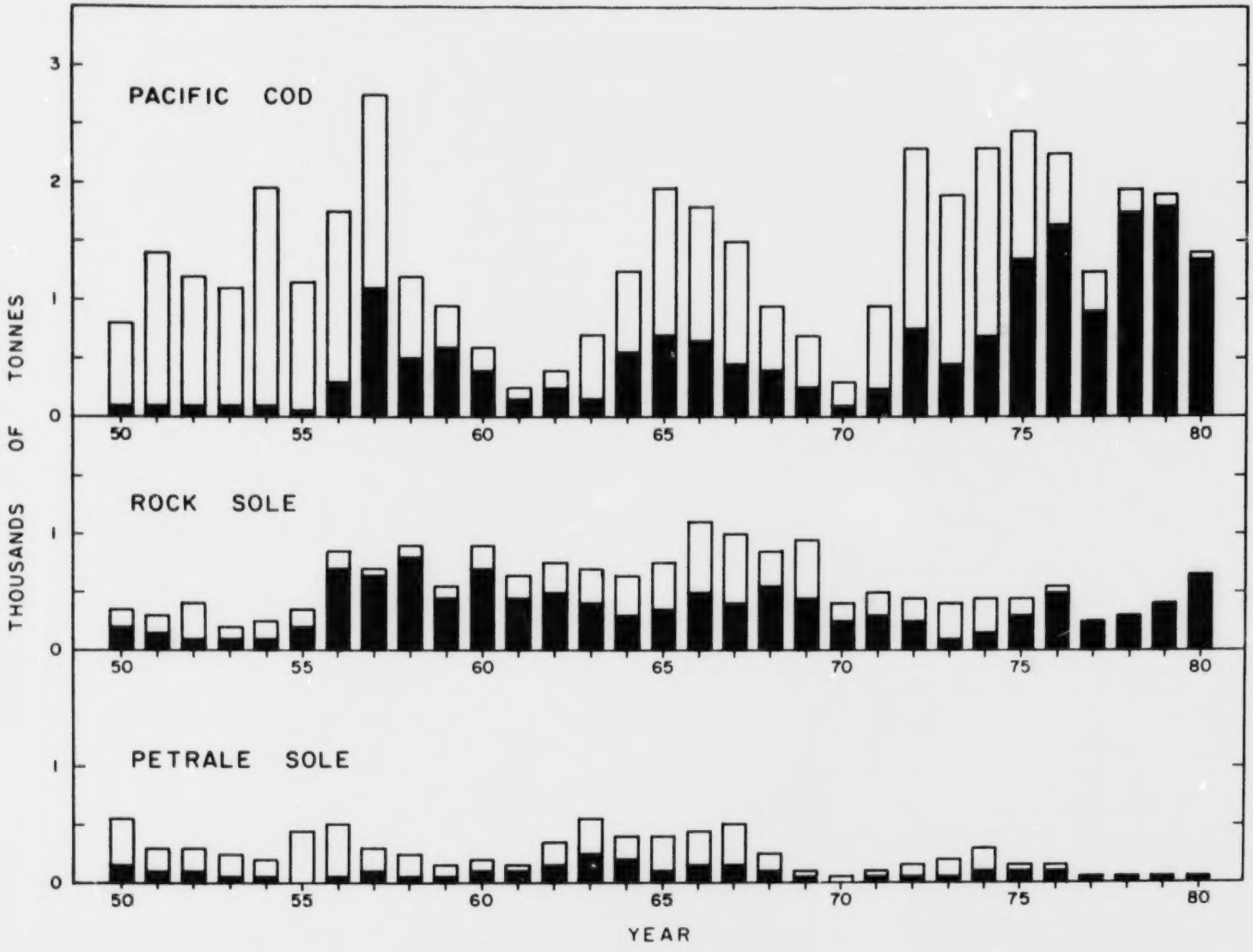

Fig. 3. Canada-U.S. landings (t) of Pacific cod, rock sole, and petrale sole from Queen Charlotte Sound (Areas 5A and 5B), 1950-80. (Shaded area = Canadian landings.)

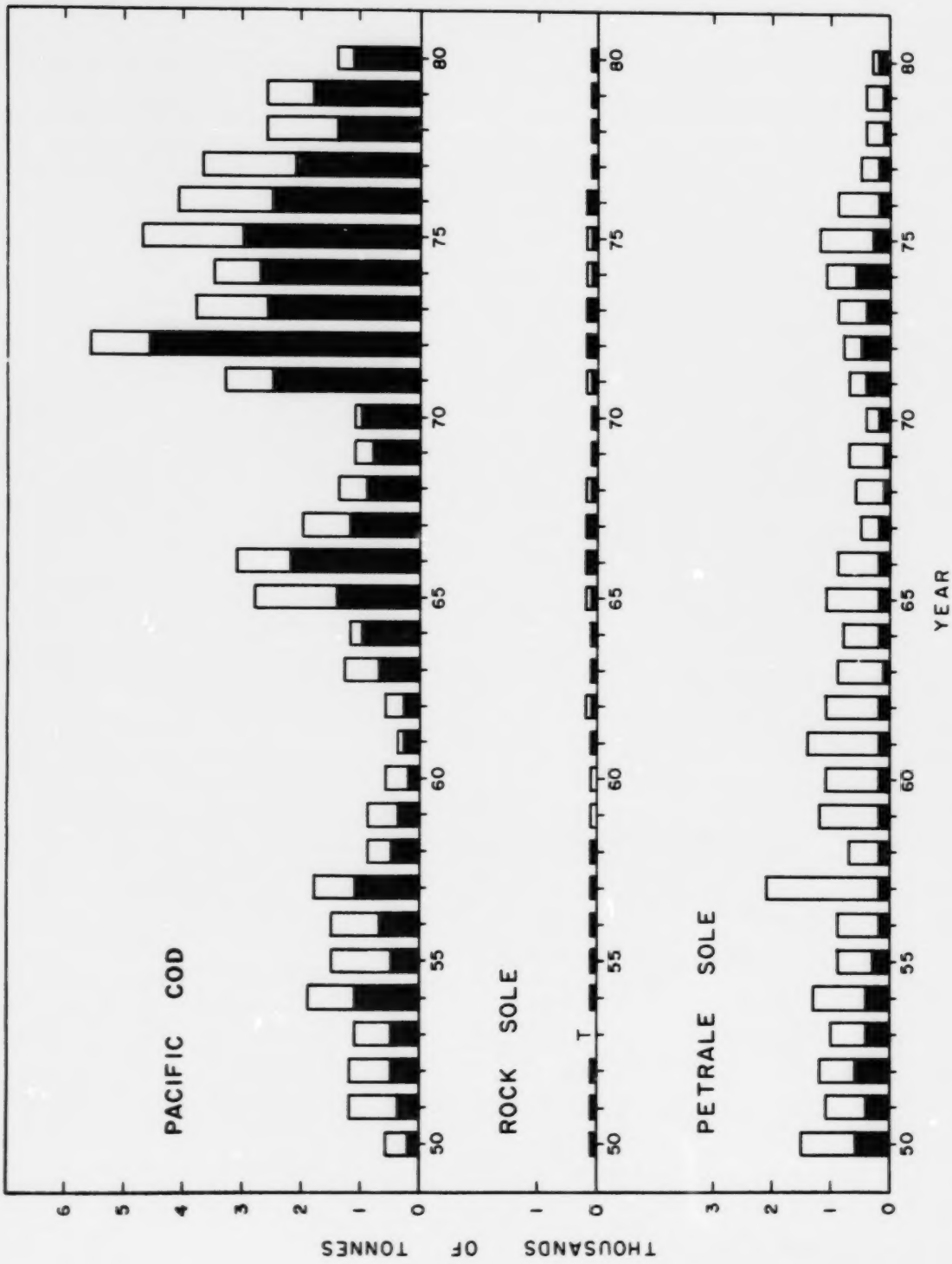

Fig. 4. Canada-U.S. landings (t) of Pacific cod, rock sole, and petrale sole from off west Vancouver Island (Areas 3C and 3D), 1950-80. (Shaded area = Canadian landings.)

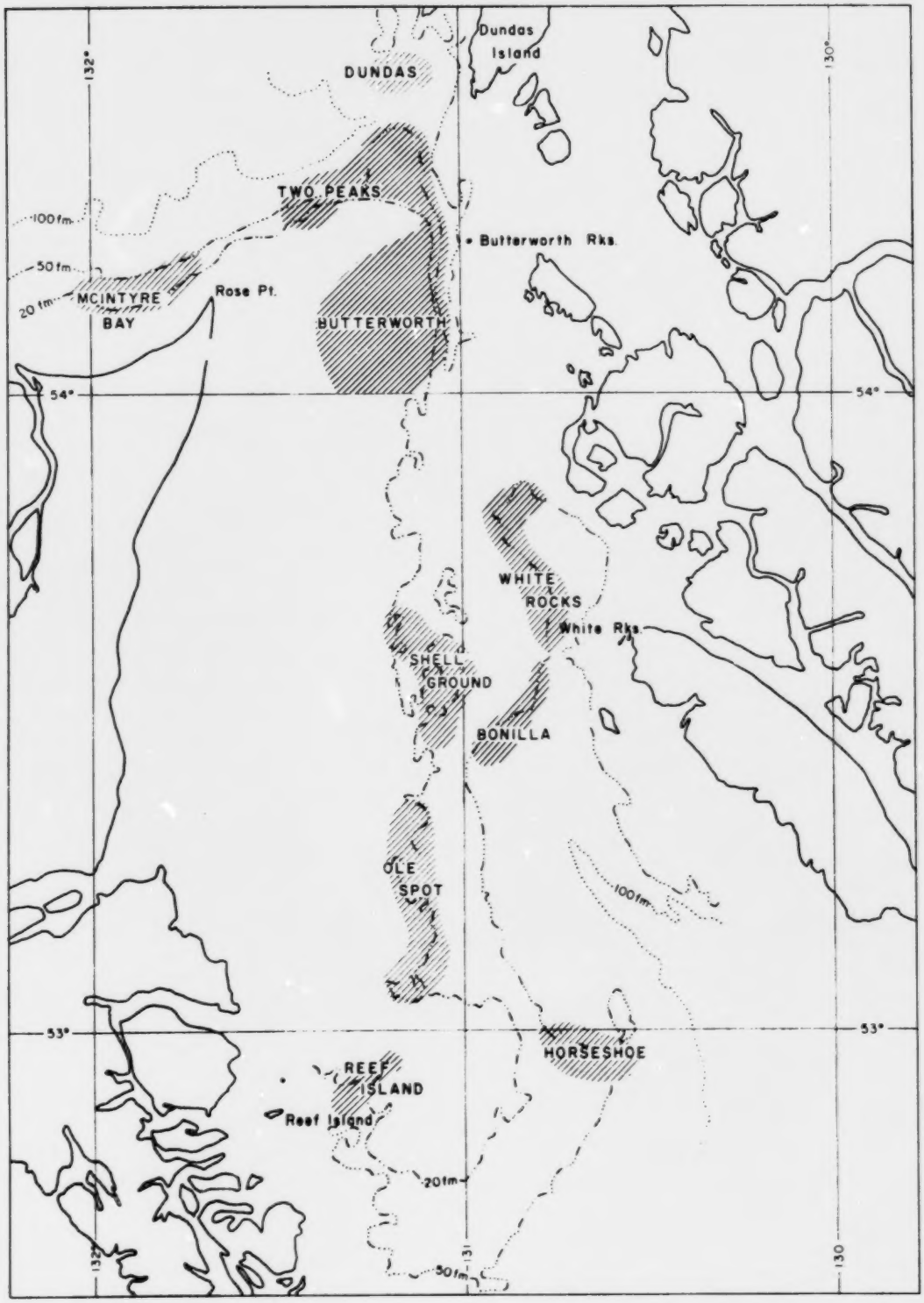

Fig. 5. Principal trawling grounds in Hecate Strait (Areas 5C and 5D).

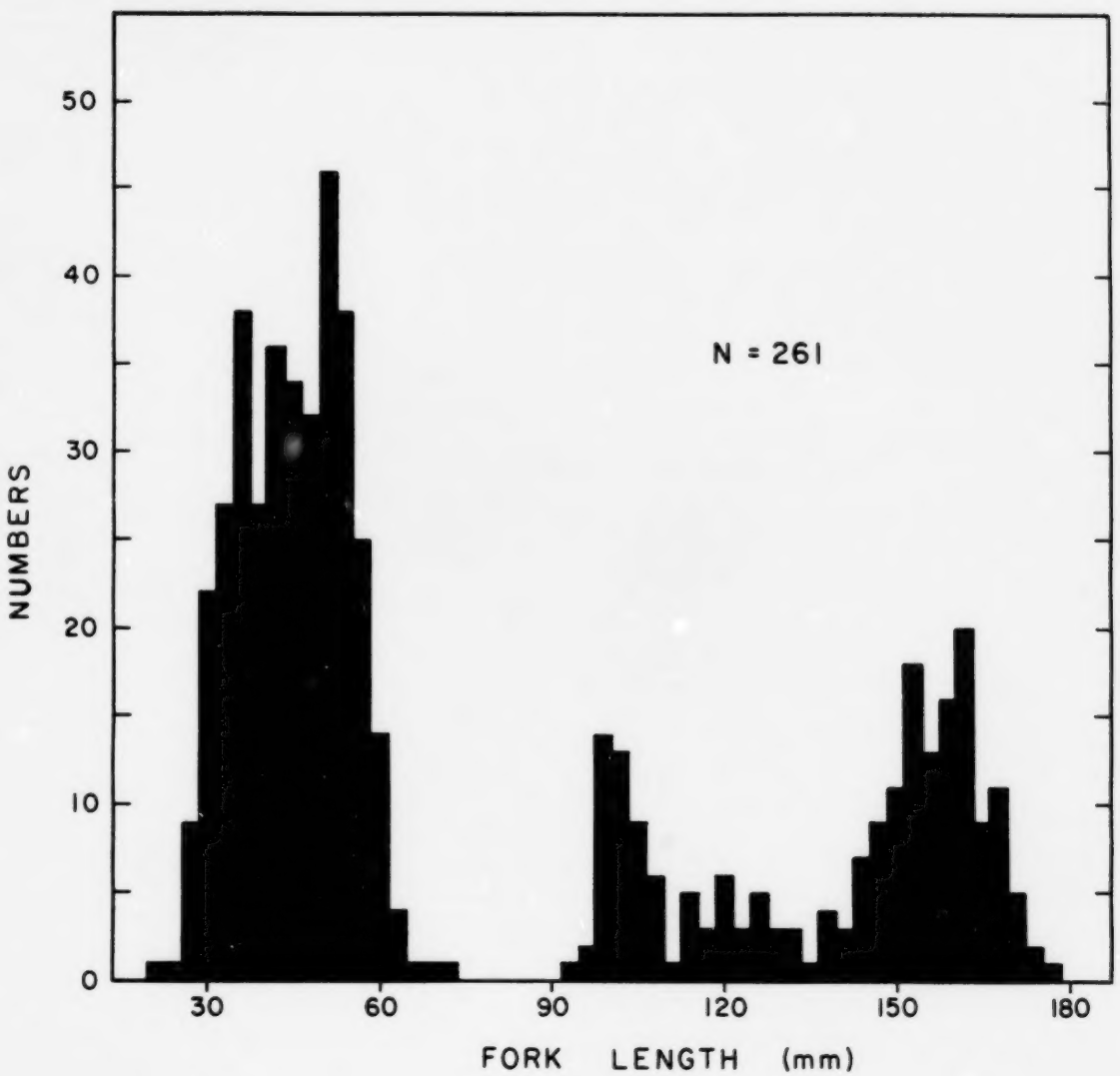

Fig. 6. Length-frequency (numbers measured) of sandlance caught by midwater trawl in Queen Charlotte Sound, June 1966.

Appendix Table 1. Incidence (numbers of samples) of principal prey species reported in evaluated samples of Pacific cod from Hecate Strait (Areas 5C + 5D), by year, 1950-80.

Year	Evaluated samples	Numbers of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	5	3	2	0	0	3	1
51	3	1	0	0	0	3	0
52	1	1	0	0	0	1	0
53	0	-	-	-	-	-	-
54	10	3	5	1	1	1	1
1955	9	4	2	0	1	3	2
56	3	0	3	0	0	0	0
57	6	5	1	0	0	0	0
58	18	8	15	1	4	0	0
59	28	6	18	3	1	0	0
1960	16	8	10	1	8	0	0
61	9	5	3	2	3	0	0
62	12	4	6	1	2	1	0
63	6	2	3	1	1	0	0
64	16	9	6	4	0	1	1
1965	17	12	5	0	0	2	0
66	17	16	0	0	0	0	1
67	2	2	0	1	0	0	0
68	2	2	0	0	0	0	0
69	1	1	0	0	0	0	0
1970	0	-	-	-	-	-	-
71	0	-	-	-	-	-	-
72	0	-	-	-	-	-	-
73	7	2	4	0	0	1	0
74	3	2	1	1	0	0	0
1975	3	1	2	0	1	0	0
76	6	4	1	0	0		0
77	13	4	5	4	1	2	0
78	18	12	6	3	2	2	0
79	37	23	2	7	7	3	2
1980	36	17	17	3	3	12	0
Total	304	157	117	33	48	38	8

[a]Other:

Vertebrates	Invertebrates
Arrowtooth flounder (Atheresthes stomias)	Clams
English sole (Parophrys vetulus)	Crab
Pacific cod (19-26 cm)	Eggs
Poacher (Agonidae)	Molluscs
Red cod (Sebastes sp.)	Munidae
Rock sole (12 cm)	Mussels
Sculpin (Cottidae)	Octopus
Shiners (Cymatogaster)	Squid
Sole, small or 20-25 cm (Pleuronectiformes)	Starfish
	Gravel

Appendix Table 2. Incidence (number of samples) of principal prey species reported in evaluated samples of Pacific cod from Queen Charlotte Sound (Areas 5A + 5B), by year, 1950-80.

Year	Evaluated samples	Number of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	2	2	0	0	0	0	0
51	1	1	0	0	0	0	0
52	0	-	-	-	-	-	-
53	1	1	0	0	0	0	0
54	0	-	-	-	-	-	-
1955	0	-	-	-	-	-	-
56	0	-	-	-	-	-	-
57	1	1	0	0	0	0	0
58	0	-	-	-	-	-	-
59	1	1	1	0	0	0	0
1960	0	-	-	-	-	-	-
61	0	-	-	-	-	-	-
62	0	-	-	-	-	-	-
63	0	-	-	-	-	-	-
64	0	-	-	-	-	-	-
1965	2	2	0	0	0	0	0
66	1	1	0	0	0	0	0
67	0	-	-	-	-	-	-
68	1	1	0	0	0	0	0
69	0	-	-	-	-	-	-
1970	0	-	-	-	-	-	-
71	0	-	-	-	-	-	-
72	0	-	-	-	-	-	-
73	0	-	-	-	-	-	-
74	2	1	0	1	0	0	0
1975	0	-	-	-	-	-	-
76	3	3	0	0	0	0	0
77	12	7	7	5	1	0	0
78	23	23	10	3	2	3	0
79	7	6	2	0	0	0	0
1980	9	5	6	1	0	0	0
Total	66	55	26	10	3	3	0

[a] Other:

Vertebrates

Arrowtooth flounder (Atheresthes stomias)
Dabs (Bothidae)
Eulachon (Thaleichthys pacificus)
Pacific cod
Sole (Pleuronectiformes)

Invertebrates

Crab
Munidae

Appendix Table 3. Incidence (numbers of samples) of principal prey species reported in evaluated samples of Pacific cod from off west Vancouver Island (Areas 3C + 3D), by year, 1950-80.

Year	Evaluated samples	Number of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	0	-	-	-	-	-	-
51	2	1	0	1	0	0	0
52	3	3	0	0	0	0	0
53	2	1	1	2	0	0	0
54	2	1	1	1	0	0	0
1955	0	-	-	-	-	-	-
56	0	-	-	-	-	-	-
57	0	-	-	-	-	-	-
58	0	-	-	-	-	-	-
59	0	-	-	-	-	-	-
1960	1	1	0	0	0	0	0
61	0	-	-	-	-	-	-
62	0	-	-	-	-	-	-
63	0	-	-	-	-	-	-
64	3	2	0	0	0	0	1
1965	2	2	0	0	0	0	0
66	5	3	0	1	0	1	0
67	0	-	-	-	-	-	-
68	1	0	0	1	0	0	0
69	0	-	-	-	-	-	-
1970	0	-	-	-	-	-	-
71	0	-	-	-	-	-	-
72	0	-	-	-	-	-	-
73	4	4	0	1	0	1	0
74	4	3	2	3	0	1	0
1975	2	0	2	0	0	0	0
76	3	1	3	0	0	0	0
77	6	1	5	1	0	0	0
78	18	11	6	4	0	5	1
79	17	11	12	1	1	6	0
1980	8	4	4	0	0	3	0
Total	83	49	36	16	1	17	2

[a]Other:

Vertebrates

Cod (sm; lge) (Gadidae)
Lingcod (14 cm) (Ophiodon elongatus)
Pacific cod (juvenile)
Petrale sole
Poacher (Agonidae)
Rockfish (Scorpaenidae)
Sculpin (Cottidae)
Sebastes proriger (redstripe rockfish)
Slender sole (Lyopsetta exilis)
Sole (Pleuronectiformes)
Tomcod (22 cm) Microgadus proximus)
Walleye pollock (28-30 cm) (Theragra chalcogramma)

Invertebrates

Crab
Octopus
Squat lobster (Munidae)
Squid

Appendix Table 4: Incidence (numbers of samples) of principal prey species reported in evaluated samples of rock sole from Hecate Strait (Areas 5C + 5D), by year, 1950-80.

Year	Evaluated samples	Number of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	11	8	1	1	0	4	0
51	23	17	1	1	0	0	5
52	25	6	0	0	0	0	19
53	17	6	0	2	0	1	8
54	21	17	0	2	0	0	4
1955	25	25	0	0	0	0	0
56	12	2	0	0	0	1	9
57	32	26	1	0	0	0	6
58	42	20	1	1	0	0	21
59	8	4	1	2	0	1	1
1960	10	4	0	0	0	4	2
61	6	1	0	2	0	1	2
62	10	2	0	1	0	1	6
63	10	3	0	2	0	0	5
64	20	16	0	3	0	0	4
1965	11	10	0	1	0	0	1
66	35	31	0	4	0	0	2
67	20	11	0	0	0	0	9
68	13	10	0	1	0	0	2
69	11	7	0	1	0	1	3
1970	5	2	0	1	0	2	1
71	6	5	0	0	0	2	0
72	0	0	0	0	0	0	0
73	2	2	0	0	0	0	0
74	0	0	0	0	0	0	0
1975	3	3	0	0	0	1	0
76	1	1	0	0	0	0	0
77	6	4	0	1	0	0	1
78	4	3	0	0	0	1	0
79	14	8	0	2	0	5	2
1980	7	5	0	2	0	0	1
Total	410	259	5	30	0	25	114

[a] Other:

Vertebrates	Invertebrates
-	Bivalves
	Clams
	Crab (sm)
	Molluscs
	Mussels
	Shell (broken)
	Shellfish
	Squat lobster (Munidae)
	Squid
	Worms

Appendix Table 5. Incidence (numbers sampled) of principal prey species reported in evaluated samples of rock sole from Queen Charlotte Sound (Areas 5A + 5B), by year, 1950-80.

Year	Evaluated samples	Number of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	5	3	0	0	0	2	1
51	2	2	0	0	0	0	0
52	6	5	0	0	0	1	1
53	4	2	0	0	0	2	0
54	6	5	0	1	0	1	0
55	2	2	0	0	0	0	0
56	5	5	0	1	0	0	0
57	11	9	0	0	0	0	2
58	15	14	0	0	0	0	1
59	17	12	0	0	0	0	5
1960	17	14	0	0	0	1	2
61	21	20	0	0	0	2	0
62	29	22	0	4	0	3	3
63	18	10	0	4	0	0	7
64	17	12	0	0	0	0	5
1965	8	8	0	0	0	0	0
66	15	14	0	1	0	0	0
67	11	11	0	0	0	0	0
68	13	12	0	2	0	0	1
69	12	9	0	0	0	0	3
70	0	-	-	-	-	-	-
71	2	2	0	0	0	0	0
72	0	-	-	-	-	-	-
73	0	-	-	-	-	-	-
74	0	-	-	-	-	-	-
1975	0	-	-	-	-	-	-
76	2	1	0	1	0	0	0
77	3	3	0	0	0	0	0
78	7	5	0	0	0	0	2
79	11	10	0	3	0	0	1
1980	5	2	0	0	0	2	1
Total	264	214	0	17	0	14	35

[a] Other:

Vertebrates

Fish
Rockfish (Scorpaenidae)

Invertebrates

Brittle starfish
Clams
Crab (sm)
Crustacea
Molluscs
Squid
Worms

Appendix Table 6. Incidence (numbers of samples) of principal prey species reported in evaluated samples of rock sole from off west Vancouver Island (Areas 3C + 3D), by year, 1950-80.

Year	Evaluated samples	Numbers of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	17	12	0	6	0	3	2
51	8	5	0	6	0	3	0
52	4	3	0	0	0	0	1
53	4	4	0	0	0	0	0
54	5	2	0	2	0	1	1
1955	1	1	0	0	0	0	0
56	0	-	-	-	-	-	-
57	0	-	-	-	-	-	-
58	4	3	0	2	0	0	0
59	0	-	-	-	-	-	-
1960	1	0	0	0	0	1	0
61	0	-	-	-	-	-	-
62	3	3	0	0	0	0	0
63	0	-	-	-	-	-	-
64	5	5	0	0	0	0	0
1965	1	1	0	0	0	0	0
66	6	5	0	1	0	1	0
67	1	1	0	0	0	0	0
68	0	-	-	-	-	-	-
69	0	-	-	-	-	-	-
1970	0	-	-	-	-	-	-
71	0	-	-	-	-	-	-
72	0	-	-	-	-	-	-
73	1	1	0	0	0	0	0
74	0	-	-	-	-	-	-
1975	0	-	-	-	-	-	-
76	0	-	-	-	-	-	-
77	0	-	-	-	-	-	-
78	0	-	-	-	-	-	-
79	0	-	-	-	-	-	-
1980	0	-	-	-	-	-	-
Total	61	46	0	17	0	9	4

[a]Other: Vertebrates

-

Invertebrates

Brittle starfish
Crab
Worms

Appendix Table 7. Incidence (numbers of samples) of principal prey species reported in evaluated samples of petrale sole from Hecate Strait (Areas 5C + 5D), by year, 1950-80.

Year	Evaluated samples	Numbers of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	4	0	3	2	0	3	0
51	9	5	2	2	0	0	0
52	0	-	-	-	-	-	-
53	3	1	2	2	0	0	0
54	0	-	-	-	-	-	-
1955	0	-	-	-	-	-	-
56	1	1	0	-	0	0	0
57	12	5	7	1	0	1	0
58	12	5	5	5	0	0	0
59	2	2	0	0	0	0	0
1960	5	3	2	2	0	0	0
61	4	0	2	1	0	3	0
62	7	1	1	0	0	3	3
63	2	0	0	1	0	2	0
64	4	1	1	2	0	1	0
1965	5	4	0	1	0	0	1
66	3	3	0	0	0	0	0
67	5	3	0	0	0	0	0
68	2	0	0	0	0	0	0
69	0	-	-	-	-	-	-
1970	1	0	0	3	0	1	0
71	1	0	1	2	0	0	0
72	0	-	-	-	-	-	-
73	0	-	-	-	-	-	-
74	0	-	-	-	-	-	-
1975	0	-	-	-	-	-	-
76	0	-	-	-	-	-	-
77	0	-	-	-	-	-	-
78	0	-	-	-	-	-	-
79	0	-	-	-	-	-	-
1980	0	-	-	-	-	-	-
Total	82	34	26	24	0	14	4

[a]Other:

Vertebrates

Fish
Pacific cod
Poachers
Rockfish (5-7 cm) (Scorpaenidae)
Smelt (Osmeridae)

Invertebrates

Crabs (hermit)
Mussels
"Spawn"
Squid

Appendix Table 8. Incidence (numbers of samples) of principal prey species reported in evaluated samples of petrale sole from Queen Charlotte Sound (Area 5A + 5B), by year, 1950-80.

Year	Evaluated samples	Numbers of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	7	3	1	4	0	2	1
51	1	0	0	1	0	0	0
52	3	2	1	2	0	0	0
53	4	1	2	2	0	1	0
54	3	1	2	1	0	0	0
1955	1	0	1	1	0	0	0
56	1	1	0	0	0	0	0
57	6	6	0	0	0	0	0
58	10	7	2	4	0	0	1
59	5	4	0	1	0	0	0
1960	7	7	0	0	0	0	0
61	6	6	0	1	0	0	0
62	21	18	0	4	0	0	2
63	17	15	0	7	0	0	0
64	14	14	0	1	0	0	0
1965	4	4	0	1	0	0	0
66	8	8	0	3	0	1	0
67	7	5	1	4	0	0	0
68	3	3	0	1	0	0	0
69	0	-	-	-	-	-	-
1970	0	-	-	-	-	-	-
71	0	-	-	-	-	-	-
72	0	-	-	-	-	-	-
73	0	-	-	-	-	-	-
74	1	0	0	1	0	0	0
1975	0	-	-	-	-	-	-
76	0	-	-	-	-	-	-
77	0	-	-	-	-	-	-
78	0	-	-	-	-	-	-
79	0	-	-	-	-	-	-
1980	0	-	-	-	-	-	-
Total	129	105	10	39	0	4	4

[a]Other:

Vertebrates

Fish
Rockfish (sm) (Scorpaenidae)

Invertebrates

Crab
Munidae
Octopus
Worms

Appendix Table 9. Incidence (numbers of samples) of principal prey species reported in evaluated samples of petrale sole from off west Vancouver Island (Areas 3C + 3D), by year, 1950-80.

Year	Evaluated samples	Numbers of samples containing:					
		Sandlance	Herring	"Shrimp"	Sablefish	Other[a]	Nil
1950	57	9	22	46	0	2	2
51	20	2	8	14	0	3	0
52	21	8	11	14	0	2	1
53	30	10	16	21	0	3	0
54	24	3	12	20	0	1	0
1955	13	1	6	11	0	2	0
56	8	3	4	5	0	0	1
57	2	1	0	2	0	0	0
58	17	4	10	16	0	1	1
59	10	6	3	9	0	0	0
1960	14	5	1	5	0	7	1
61	20	8	6	11	0	4	0
62	15	10	2	11	0	1	1
63	4	2	0	3	0	0	0
64	14	10	2	5	0	0	4
1965	13	9	3	9	0	0	0
66	11	8	1	6	0	0	0
67	11	9	0	6	0	0	0
68	6	2	4	2	0	0	0
69	7	2	5	6	0	0	0
1970	3	0	1	3	0	0	0
71	8	4	3	7	0	0	0
72	3	1	0	2	0	0	0
73	2	0	0	2	0	0	0
74	9	6	4	8	0	0	0
1975	1	0	0	1	0	0	0
76	1	1	0	1	0	1	0
77	3	1	2	2	0	0	0
78	3	0	3	3	0	0	0
79	1	1	0	0	0	1	0
1980	1	0	0	0	0	0	1
Total	352	126	129	251	0	28	12

[a] Other:

Vertebrates

Fish
"Minnows"
Pacific cod (6 cm)
Poacher (Agonidae)
Rockfish (Scorpaenidae)
Smelt (Osmaridae)
Sole (Pleuronectiformes)

Invertebrates

Crabs
Munidae
Polychaetes
Squid
Worms

Appendix Table 10. Size classes[a] of sandlance in evaluated samples of Pacific cod, rock sole, and petrale sole, by region and year, 1950-80.

	Hecate Strait (5C + 5D)			Queen Charlotte Sound (5A + 5B)			W. Vancouver Is. (3C + 3D)		
Year	S	M	L	S	M	L	S	M	L
1950	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	9	-
1954	-	1	-	-	1	-	-	-	-
1955	1	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	1	-	-	-
1958	1	-	-	-	-	2	-	-	-
1959	2	-	-	1	-	2	-	-	-
1960	3	-	-	4	-	-	-	-	-
1961	-	-	-	3	-	1	-	-	-
1962	-	1	-	-	7	2	1	-	-
1963	2	1	-	3	2	-	-	-	-
1964	-	-	-	9	1	1	-	-	-
1965	9	3	-	5	1	-	2	-	-
1966	18	1	2	5	-	2	2	2	2
1967	4	1	1	3	6	1	-	2	1
1968	6	-	1	2	4	-	-	-	1
1969	1	-	1	1	-	3	-	-	-
1970	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	1	-	-
1972	-	-	-	-	-	-	1	-	-
1973	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-

[a] L = large (> 15 cm); M = medium (≈ 15 cm); S = small (≈ 8 cm).